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# Not just Norbert

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## Abstract

*Purpose:* Although Norbert Wiener is justifiably granted the epithet ‘father of cybernetics’, a number of other engineers from a control or telecommunications background also turned to areas that can broadly be categorised as cybernetic during and immediately after WW2. This paper gives an overview of some of these lesser-known technologist contributors to the emerging ideas of cybernetics.

*Approach:* The paper is based on primary and secondary literature, as well as two interviews from the early 1990s.

*Findings:* In Germany Hermann Schmidt, chair of the *Verein Deutscher Ingenieure* [Society of German Engineers] committee on control engineering (established in 1939) gave a talk on control engineering and its relationship with economics, social sciences and cultural aspects as early as October 1940. Winfried Oppelt, another member of the committee, also researched non-technological applications of control ideas in his subsequent career (economics, biology), as did the communications engineer Karl Küpfmüller (pharmacokinetics, models of the human nervous system). In the UK, Arnold Tustin developed a mathematical model of a human gun operator during the war, and then applied control ideas to economic systems from the mid 1940s.

*Originality:* The material presented here is not well known even within the control and communications engineering sectors, and is largely absent from histories of cybernetics – at least those in the English language.

*Keywords:* cybernetic modelling, history, Küpfmüller, Schmidt, Oppelt, Tustin

*Classification:* General review

## Introduction

The story of how Norbert Wiener was inspired by his WW2 work on feedback control of anti-aircraft guns to generalise it to communication and control in humans, animals and machines has often been told; indeed, it has become a central part of histories of the discipline of cybernetics. Typical of reference work entries relating to him are the following:

During World War II, [Wiener’s] work on the automatic aiming and firing of anti-aircraft guns led [him] to communication theory and eventually to formulate cybernetics. [...] Wiener went on to break new ground in cybernetics, robotics, computer control, and automation. He shared his theories and findings with other researchers, and credited the contributions of others. These included Soviet researchers and their findings (wikipedia.org, accessed 11 August 2009).

During World War II Wiener worked on the problem of aiming gunfire at a moving target. [...] This work also led him to formulate the concept of cybernetics. In 1948 his book *Cybernetics; or, Control and Communication in the Animal and the Machine* was published. For a scientific book it was extremely popular, and Wiener became known in a much broader scientific community. Cybernetics is interdisciplinary in nature; based on common relationships between humans and machines, it is used today in control theory, automation

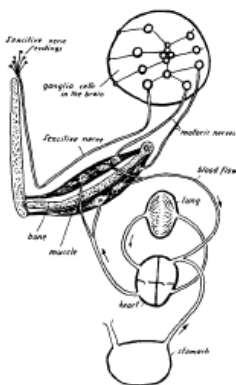
theory, and computer programs to reduce many time-consuming computations and decision-making processes formerly done by human beings (Encyclopedia Britannica, 2004).

Even Freudenthal's less than positive short paragraphs on cybernetics in the *Dictionary of Scientific Biography* make similar points:

[...] While studying antiaircraft fire control, Wiener may have conceived the idea of considering the operator as part of the steering mechanism and of applying to him such notions as feedback and stability, which had been devised for mechanical systems and electrical circuits. No doubt this kind of analogy had been operative in Wiener's mathematical work from the beginning and sometimes had even been productive. As time passed, such flashes of insight were more consciously put to use in a sort of biological research for which Wiener consulted all kinds of people, except mathematicians, whether or not they had anything to do with it. *Cybernetics, or Control and Communication in the Animal and the Machine* (1948) is a rather eloquent report of these abortive attempts, in the sense that it shows there is not much to be reported. The value and influence of *Cybernetics*, and other publications of this kind, should not, however, be belittled. It has contributed to popularizing a way of thinking in communication theory terms, such as feedback, information, control, input, output, stability, homeostasis, prediction, and filtering. On the other hand, it also has contributed to spreading mistaken ideas of what mathematics really means [...] (Freudenthal, 2008)

What is not often made clear in such (hi)stories is that Wiener was just one of many scientists, mathematicians and engineers working on such feedback problems in a variety of countries. A number of them, as this paper will demonstrate, independently realised that by adopting a "systems approach" human beings could be incorporated into overall models, just as common analysis and design techniques could be applied to electrical, electronic, mechanical and other engineered components. Wiener himself had little to say about such contemporaries – even those of whom he was certainly aware. Indeed, David Mindell, in his major study of the history of feedback control in the United States, goes so far as to remark upon "Wiener's consistent failure to acknowledge the multiple traditions of feedback engineering that preceded him" (Mindell, 2002). Furthermore, it is rarely recorded that a number of other contemporary control and communications engineers independently studied wider applications of the new feedback control theory in biological, social and economic systems. This brief paper will outline the relevant work of a number of such contemporaries of Wiener – work which is not well known even within the control engineering profession, and which does not appear to have featured to any great extent in general histories of cybernetics proper. It will concentrate on the activities of four wartime and post-war researchers, three Germans and one Englishman. While it is not claimed that these figures are central to the history of cybernetics, their work is certainly of significant interest and should be better known.

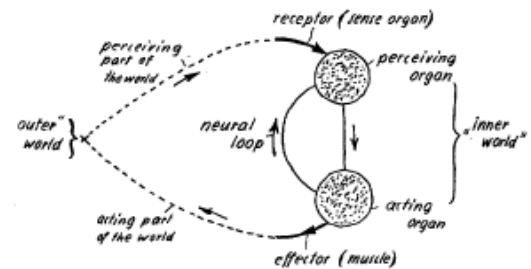
## Cybernetic 'prehistory' in Germany



As early as 1879, Felix Linke, Professor of Mechanical Engineering at the Polytechnikum Darmstadt, had recognised the parallel between the human body and mechanical servomechanisms, and had presented a number of drawings representing signal flows, blood flows and feedback in a what might be termed a 'proto-cybernetic' manner. Left is one of his illustrations as re-drawn by Oppelt (1984).

Lincke distinguished between what he called the *indicator*, *modifier*, *transmitter* and *motor* in both mechanical and biological systems, in a manner prescient of both cybernetics and mechatronics.

By the 1920s a number of biologists were developing such ideas further (Henn, 1969); one of the most interesting early German contributions is that of Von Üexküll (1920), who explicitly represented signal flows both within an organism and between the organism and its environment. On the right is another re-drawing by Oppelt (1984). While it is not clear how well aware later German engineer contributors were of this heritage (and there were, of course, a number of other philosophers and biologists who were coming to similar conclusions in the 1920s and 1930s, of whom Ludwig von Bertalanffy is perhaps the best known), it is interesting to note a pre-war German milieu in which such notions were being formed. Another significant German figure from the field of physiology was Richard Wagner, who wrote a series of articles in the 1920s on biological systems involving feedback (Dittmann, 2009).



### Hermann Schmidt and *Allgemeine Regelungskunde*



Hermann Schmidt, a physicist by training and a qualified university teacher with a *Habilitation* (a second advanced thesis required in Germany for university academic posts), joined the German patent office in 1930, where he was responsible for patents in the area of control systems for technical processes. This professional activity brought him into contact with a range of control devices, and he began to realise the generic nature of control engineering and its applicability to non-technical areas. In 1939 he was asked to chair a new control engineering committee of the VDI – *Verein Deutscher Ingenieure*, one of the two major engineering professional bodies in Germany. As early as October 1940, the committee organised a conference on the topic, including papers on flight control, the inner ear, blood circulation and precision engineering. Schmidt himself gave a wide-ranging introductory address subsequently published, as were the other papers, in the VDI's journal (Schmidt, 1941a). In this address, entitled "Control engineering: the technical task and its economic, socio-political and cultural implications" Schmidt looked at a range of applications of the emerging discipline, stating:

As soon as we are convinced that all technical and non-technical feedback systems are closely related, these relationships must not be distinguished by their specific designs in anatomy or technology; on the contrary their only common characterisation is the analogy of signal flows and the dynamics of control.

His notion of *Allgemeine Regelungskunde* [general control theory] was applicable, he claimed, not only to engineering but also to such areas as biology, physiology and economics. For example:

... the physiologist is forced to use simplified schemes or models for the description of organic regulation processes. He finds such simplified schemes in regulation technology in a great variety of forms, as if ready made for his use. [...] The state can also be viewed in some of its activities as a regulator of free forces ...

In 1941, in a memorandum to the VDI Chair, Schmidt called for the establishment of an Institute of Control Engineering to study application areas in industry, the military, biology and society, with the aim – in what became a famous aphorism modelled on Galileo’s alleged (Kleinert, 2009) remark about measurement – “to control everything that is controllable, and to render controllable that which cannot yet be controlled” (Schmidt, 1941b). After some negotiations, a chair in control engineering was finally established in Berlin in late 1944, and Schmidt was appointed – briefly – to the position.

Schmidt’s wide-ranging approach to control ideas certainly anticipated many of the cybernetics ideas championed by Wiener after the war (Dittman & Ségal, 1997; Dittman, 1999-2000; Fasol, 2001, 2002), but it was some time before he could return to the theme in earnest. He spent the first six postwar years in East Germany, being required by the Soviet occupying powers to work on control projects there. On his return to the West, his cybernetic ideas were not always accepted by colleagues (Fasol, 2001), and the fact that he had been a Nazi party member from 1938-1945 (most likely simply as a career move) certainly did not help in some post-war circles\*. Now, however, he is increasingly recognised as a German pioneer of early cybernetics (Fasol, 2002). He was reappointed to full Professor in Berlin in 1954 and for the next decade or so combined teaching conventional control engineering with more general speaking and writing on cybernetic topics.

### Winfried Oppelt

Winfried Oppelt was another control engineer who served on Schmidt’s wartime committee. Oppelt came from a physics and aeronautical background, and had worked on flight control systems. As early as 1937, however, he gave a conference paper in which he compared flight control to other systems, recognising (as had Schmidt), the commonality in a wide range of applications (Bissell, 1992a). Of the committee’s work, Oppelt later wrote:



I like to think back to the work of the specialist VDI committee. There prevailed an open-minded and free-thinking atmosphere, which promoted creativity. The entire field of control [...] was discussed. This had, of course, very stimulating and far-reaching effects [...] (Oppelt, 1984).

And again:

[The committee] was an astonishing experience for me – and for the other members as well – to be able to meet at that time and discuss technical matters without worrying about who was competing with whom. We produced a report at the end of the war on concepts and terminology in control engineering, which subsequently formed the basis of later work on the first DIN standard in control engineering” (Bissell, 1992a).

Oppelt’s immediate postwar history was very different from Schmidt’s. For a couple of years he lived quietly in the Western Zone, writing the first edition of a renowned textbook on control engineering that was to be expanded and revised over the following decades: the fifth edition in 1972 ran to 770 pages. From 1956 onwards Oppelt occupied the Chair of control engineering at Darmstadt Technical University, but he retained an interest in non-technical applications of control theory in such areas as cybernetics, biology and economics.

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\* There is no simple causal link between the postwar fortunes of German scientists and the extent to which they had been involved in the Nazi regime. Some active former party (and even SS) members quickly took up successful careers again, while other scientists who had been only passive or peripheral participants found it difficult to regain their former status.

In the mid 1950s the VDI held a number of conferences on the non-engineering applications of control theory. In April 1954 there was a two-day meeting on biological control mechanisms in Darmstadt (Mittelstaedt, 1956) and in March 1955 a similar one in Essen on the links between processes in economics and those in engineering (Geyer & Oppelt, 1957). At both events Oppelt gave introductory talks setting the scene for the ways in which control engineering ideas could contribute to an understanding of biological and economic systems.

Later in life Oppelt continued to be fascinated by other applications of control, cybernetics and systems theory in biology, and continued to work – and publish – on hypnosis right up until his death. In 1970, for example, he co-edited a collection, *Man as regulator*, that reported work of the 1960s (mainly from Eastern Europe) covering both humans within control systems and control systems within the human body (Oppelt & Vossius, 1970). The book received a (belated) favourable review in *IEEE Transactions on Systems, Man and Cybernetics*.

The emphasis of this book is on modeling, in the precise engineering sense, of a variety of phenomena that are regulated by a human being consciously or unconsciously. With minor exceptions, there is no attempt to justify the models or demonstrate their usefulness in medicine, orthoses, prostheses, or other tasks. However, the book's most valuable asset is the integration of engineering sciences and biology to a very sophisticated and effective degree. For those who know the fundamentals of system theory and can read German, this book not only provides pleasure and inspiration but also vistas of future work in understanding the human organism. (Hemami, 1974)

## Karl Küpfmüller

The last of the three German pioneers to be considered here came from a rather different background. Born into a working class family, Küpfmüller's study at a polytechnic was interrupted by the First World War, and he never completed any advanced academic university studies such as a doctorate or the *Habilitation* normally required for a university career. Nevertheless, he made himself felt as a major influence on German communications and systems theory in the 1920s, authoring a number of classic papers on signal transmission and closed-loop dynamics; he was appointed to his first university post in Danzig in 1928 without the normal academic background (Bissell, 1986).



Unlike Schmidt and Oppelt, Küpfmüller played a significant role in the Nazi machine, becoming an SS officer and ultimately responsible for the German navy's scientific section – while apparently also continuing in a senior role at Siemens & Halske as well as holding a visiting professorship at Berlin Technical University (Wunderlich, 2005). Indeed, he was a member of the SA and subsequently the SS from 1933, and rose to the rank of *Obersturmbannführer* in the latter by the end of the war. He had also been a Nazi party member since 1937. Details of this aspect of his life are largely omitted from the short biographies and celebratory articles that regularly appeared on his major birthdays in the specialist German technical literature, and are mentioned only briefly or elliptically in one or two obituaries.

As a result of Küpfmüller's wartime record he was interned in 1946-7 for denazification, and during that time met the cancer researcher Hermann Druckrey, also interned. They collaborated on a study of dose-effect relations in pharmacology and toxicology, with Küpfmüller bringing his interdisciplinary ideas about modelling to the problem. Specifically, Küpfmüller applied



mathematical modelling and electrical analogue simulation to the action of carcinogens, a technique that was successfully demonstrated in practice at Rhode & Schwarz after their release, when their work also appeared as two highly influential publications.

Although Küpfmüller's professional academic appointments were generally in the field of telecommunications, culminating in a Chair at Darmstadt for the decade before his retirement in 1963, he continued to take an interest in cybernetics and biological modelling. He promoted research into speech synthesis, information processing by the nervous system, and other related areas. He was highly active in German cybernetics, including becoming honorary President of the German Society for Cybernetics in 1969, and he was one of the founders of the journal *Biological Cybernetics*.

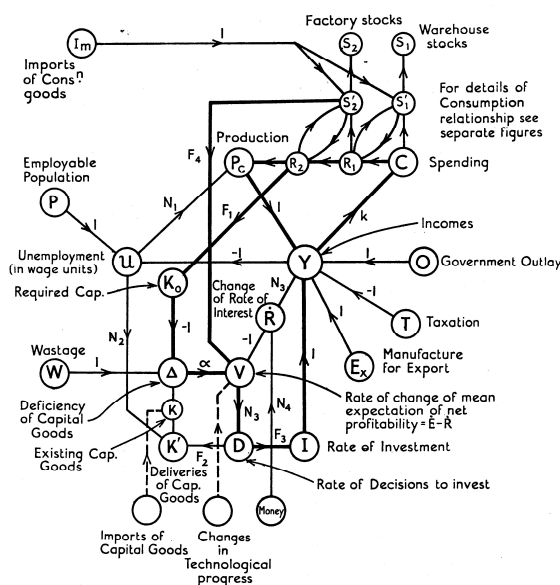
## Arnold Tustin

Arnold Tustin was an electrical engineer who worked on gun servo design at Metropolitan Vickers, one of the major British companies involved in the war effort. He was responsible for a number of innovative approaches to feedback system design and, like his German contemporaries discussed above, became intrigued by the application of control theoretical ideas to biological and social systems. During the war he devised a simple mathematical model of the response of an operator to the requirement to 'follow' the reading on an indicator in order to train a gun on its target. By modelling the motion of the operator by a simple time delay plus a first-order linear differential equation, he was able to build the human into a complete model of the control loop, thus predicting the overall system dynamics as the operator struggled to react to a changes in the desired gun aim.



Professor Arnold Tustin.

Like the Germans, Tustin became fascinated by applications of control theory beyond the technical systems he had worked on during the war, although his academic career was as professor of electrical engineering at Birmingham University and then Imperial College, London. In 1953 he published a book on modelling economic systems using control-theoretical ideas. The following figure shows a signal flow diagram taken from this work.



The eminent economist (and former engineer) A. W. H. (Bill) Phillips wrote in a review:

There are certain formal similarities between the problems of devising policies for economic stabilisation and those of designing automatic control systems. Methods have recently been developed by engineers for analysing the dynamic properties of quite complex models [...] which] can also be used for the analysis of dynamic process models in economics. [...] Professor Tustin's book contains material of fundamental importance for all who are engaged in either theoretical or empirical studies of dynamic processes in economics. It throws new light on the possibilities and the difficulties of quantitative research in this field. (Phillips, 1954)

Tustin had clearly been working on such matters for some time. In the preface to the book he commented: "I wrote the notes on which this book is based in 1946, while convalescing after an illness. These notes were read by a number of economists, who gave warm support to the idea of developing them for publication." And in 1951, at an international conference on automatic control whose organising committee he chaired, he had participated in an informal evening meeting on the behaviour of economic systems. He and the Cambridge economist J. R. N. Stone gave introductory talks, followed by general discussion by other conference participants (Tustin, 1952). In his inaugural lecture as Professor of Electrical Engineering at Imperial College in December 1955 he again indicated further applications of engineering in economics and biology. Although the title "The next ten years" implied "in electrical engineering", he ranged well beyond that discipline, not only to economics but also electroneurology and the intriguing possibility of artificial genetic manipulation (Tustin, 1955).

In later years Tustin also became interested in psychology and evolution, and continued to work, with the aid of an amanuensis (he was virtually blind), into his nineties.

## Discussion

The aim of this short paper has been to demonstrate that Norbert Wiener was part of a much broader tradition of engineers with a control and communications background who became fascinated by applications in biology and society, and who can be considered as part of the post-war cybernetic movement, even though somewhat on the periphery. Particularly noteworthy is the work of Hermann Schmidt and the VDI committee, who were developing ideas closely related to those of Wiener at around the same time, but completely independently. Tustin, too, modelled human and economic system behaviour using control ideas, again beginning his work on non-engineered systems well before Wiener's cybernetics became widely known. While none of the researchers discussed here were as novel or influential as Wiener, it is important to demonstrate the range of activities conducted during and after the Second World War by mainstream engineers in the area that can loosely be characterised as cybernetics.

All the subjects of this article held long-term, conventional, academic chairs in engineering disciplines, with associated teaching and administrative duties, and activities in professional engineering bodies. On his return to academic life after the war Schmidt was responsible for standard university courses in control engineering – but, unusually, also gave one covering the general feedback principle in science and the arts. In later life he gave many public lectures and increasingly turned his attention to anthropology, ethics, philosophy, and technology in society. None of his writings that touch on these themes appear to have been translated into English. Küpfmüller, too, was active in the general cybernetics field well into the 1960s; to the right is the cover of an important German text from that period to which he contributed (Frank, 1962).





Küpfmüller is remembered in Germany, however, primarily as the founder of linear systems theory, and for textbooks on this and on the theory of electrical engineering, both of which ran to numerous editions. These, again, were not translated into English, although his ideas were taken over into American work in the field (Bissell, 2008).

Oppelt was very much primarily the ‘grand old man’ of German control engineering, in spite of his cybernetic and biological interests, and is remembered above all for his pedagogically novel textbooks. Tustin, after the publication of his book on economics, appears to have concentrated on mainstream engineering until his retirement; in control engineering circles his name is associated primarily with a particular design approach known as the “Tustin transformation”. His work on economics, however, seems to have become widely known. He was cited by a number of the participants in the Essen conference mentioned above, and according to him in an interview just before his death his work also appeared in Japanese (Bissell, 1992b).

The ‘hard’ engineering tradition has perhaps been underplayed in histories of cybernetics, which have tended to concentrate on the Wiener – McCulloch – Macy Conferences line. What is most surprising is that a number of Europe’s most distinguished academic control, communications and electrical engineers were sufficiently stimulated by their wartime experiences to investigate areas that must have been, initially at least, extremely foreign to much of their professional background. There appears to have been something extremely powerful about the notion of feedback, and the accompanying theory that emerged in the mid 1940s, which prompted such engineers to undergo something of a revolution in their traditional world view.

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